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To: PAG members
From: Chris Van Peski

Re: Birefringence of calcium fluoride

NIST has been measuring properties of CaF2 at NIST as part of our optical materials investigation effort.

Recent measurements by John Burnett at NIST show that there is an inherent birefringence in CaF_2 that is a strong function of wavelength.

Although this is negligible at 632nm, the wavelength used to measure birefringence in most popular birefringence measurement instruments, it is approximately 6.5nm/cm at 157nm.

The birefringence requirement for lens grade material is currently 1nm/cm, moving to 0.5nm/cm for higher NA lenses.

John Burnett points out that the birefringence is seen only for light propagating in the <110> direction, and disappears in the <100> and <111> directions. Most lens elements are fabricated with the principal ray propagating in the <111> direction, so the principal ray is not affected. The marginal rays will be affected to some degree, depending on the design of the lens, and the NA.

We do not yet know if this will have an impact on imaging capability of the lenses currently under design. We will ask the exposure tool manufacturers and lens designers to look at the data and provide an assessment of it's effect on imaging capability of their lenses.

We have not yet measured the inherent birefringence of BaF_2, so we do not know if it displays the same effect, and whether the birefringence is the same sign as CaF_2.

We will keep you informed of the status.

Attached is note and graph from John Burnett.

Chris Van Peski
May 7, 2001

7 May 01

Preliminary Determination of an Intrinsic Birefringence in CaF_2

John H. Burnett, Eric L. Shirley, and Zachary H. Levine
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Gaithersburg, MD 20899

We have measured an intrinsic (not stress-related) birefringence in CaF_2 in the ultraviolet. Preliminary measurements on two samples from the same ingot give the following values:

For propagation in the [110] direction, the maximum birefringence is:

$n_{[001]} - n_{[-110]} = (6.5 \pm 0.4) \times 10^{-7}$, for $\lambda = 156.10$ nm
$n_{[001]} - n_{[-110]} = (3.6 \pm 0.2) \times 10^{-7}$, for $\lambda = 193.09$ nm
$n_{[001]} - n_{[-110]} = (1.2 \pm 0.1) \times 10^{-7}$, for $\lambda = 253.65$ nm

For propagation in the [100] and [111] directions, the birefringence is consistent with zero as predicted by theory.

The complete dependence of the intrinsic birefringence on the polarization and propagation direction in the crystal is determined and will be presented at the 2nd International Symposium on 157nm lithography, in Dana Point on 15 May.